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How Inadequate Provision of Public Infrastructure and Services Affects Private Investment

Evidence from Uganda shows that poor public provision of infrastructure services — proxied by an unreliable and inadequate power supply — significantly reduces productive private investment

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Summary findings

Lack of private investment is a serious policy problem in many developing countries, especially in Africa. Despite recent structural reform and stabilization, the investment response to date has been mixed, even among the strongest reformers.

The role of poor infrastructure and deficient public services has received little attention in the economic literature, where the effect of public spending and investment on growth is shown to be at best ambiguous.

Reinikka and Svensson use unique microeconomic evidence to show the effects of poor infrastructure services on private investment in Uganda. They find that poor public capital, proxied by an unreliable and inadequate power supply, significantly reduces productive private investment.

Firms can substitute for inadequate provision of public capital by investing in it themselves. This comes at a cost, however: the installation of less productive capital.

These results have clear policy implications. Although macroeconomic reforms and stabilization are necessary conditions for sustained growth and private investment, without an accompanying improvement in the public sector's performance, the private supply response to macroeconomic policy reform is likely to remain limited.

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The findings reported in this paper are based on data from a 1998 Uganda Enterprise Survey carried out by the Uganda Manufacturers Association Consultancy and Information Service (UMACIS) on behalf of the Ugandan Private Sector Foundation and the World Bank, and was managed by William Kalema and Frances Nzonsi. We thank the Governments of Austria and Sweden for their generous financial support of the survey.

1. Introduction

Until fairly recently, the traditional approach to growth in the development economics literature (and in policy formation) was rather mechanical: growth was constrained by lack of investment which, in turn, was constrained by lack of finance. Consequently, if finance were made available, it was argued, investment would follow (Easterly, 1997). Although underdeveloped financial systems are found to be associated with poor economic performance in cross-country regressions (King and Levine, 1993), evidence from several African countries indicates that lack of liquidity typically only constrains the capital accumulation of household and small enterprises, but on average not that of larger firms (Bigsten et al., 1999). Hence, factors other than finance must explain the apparent reluctance of firms to invest and expand.

In the extensive cross-country growth literature, the role of macroeconomic policy, proxied by government budget deficits, black-market premiums, and inflation (see for instance Easterly and Rebelo, 1993; Barro, 1991; Fisher, 1993), has been identified as a key policy measure influencing both efficiency and level of investment and growth. However, despite recent macroeconomic reforms in many developing countries, the private investment response has been disappointing, particularly in Africa (Collier and Gunning, 1999). Uganda is a good example. Over the past decade, Uganda has consistently liberalized its economy, and now has one of the best macroeconomic environments in Africa. Still, the investment response is not significantly different from other African countries with significantly worse macroeconomic environments (Reinikka and Svensson, 1999).

The role of poor infrastructure and deficient public services has received little attention in the economic literature. The existing empirical evidence, based on cross-country data, indicates that the effect of public spending and investment on growth is at best ambiguous (Barro and Sala-i-Martin, 1995; Easterly and Rebelo,1993; Devarajan, Swaroop, and Zou, 1996).[1]

This ambiguity may simply be a problem of identification; more spending does not necessarily imply more public capital or services (Pritchett, 1996; Ablo and Reinikka, 1998; Svensson, 1999a). In fact, when output measures of public capital, such as telephones per worker, rather than spending have been used to proxy infrastructure constraints, a positive relationship between infrastructure quality and growth emerges (Easterly and Levine, 1997). However, as with other outcome measures in cross-country regressions, the direction of causality is unclear, thus making it difficult to assess the relationship.

We avoid the identification problem by using unique microeconomic evidence to show the effects of poor infrastructure services on private investment in Uganda. We find that poor public capital, proxied by unreliable and inadequate public power supply, significantly reduces productive investment by firms. The microeconomic data also shows us how firms cope with deficient public capital: when public provision of services and infrastructure is poor they can invest in complementary capital themselves. However, there is a cost: less productive capital will be installed.

[1]Easterly and Rebelo (1993) find that overall public investment has a very low impact on growth, but that certain types of investment expenditures are correlated with growth. Devarajan, Swaroop, and Zou (1996) find that the standard candidates for productive expenditures had either a negative or insignificant relationship with growth.

These results have clear policy implications. Although macroeconomic reforms and stabilization are necessary conditions for sustained growth and private investment, without an accompanying improvement in the public sector's performance, the private supply response to macroeconomic policy reform is likely to remain limited.

The rest of the paper is organized as follows. Section 2 explores the stylized facts of deficient public capital from the viewpoint of firms. Section 3 sets out a simple two-period model highlighting the relationship between firms' productive investment and availability of complementary capital. The model captures salient features of low-income economies by assuming absence of a credit market, deficient supply of publicly provided complementary capital, and uncertainty about its future improvement. Section 4 tests the model empirically using recent firm survey data from Uganda. Section 5 concludes.

2. Deficient public capital: A case study of a developing country

This section stylizes some facts about deficient public capital in a typical low-income developing country. The data come from a recent (1998) firm survey in Uganda that collects information on infrastructure services and private investment. The survey covered a total of 243 firms for the period 1995-97 (Reinikka and Svensson, 1999).

We define complementary capital as capital that provides support services necessary for the operation of productive private capital (e.g. transport infrastructure, such as roads, ports, and railways; or utilities, such as electricity, water,

and telephone). In low-income countries complementary capital is typically publicly provided. In certain cases the firm can substitute for deficient public services by investing privately in complementary capital (e.g. electric power generators or waste disposal). However, some types of complementary capital, such as transport infrastructure, cannot easily be substituted.

Is poor public service perceived to be an important constraint for firms? Figure 1 ranks firm managers' perceptions on a wide range of constraints to investment. Managers rated poor utility services (and the cost of utility services) as the most binding constraint. Unreliable and inadequate electricity was ranked as most binding by most firms, followed by telephone services, roads, and waste disposal. Although most firms (94 percent) were connected to the public grid, power supply was ranked as a major obstacle for every sector and size category of firms, whether foreign or domestic. Responses suggest that the supply of electricity had in fact worsened in the recent years.

The quantitative information reveals a similar picture. On average, the firms surveyed did not receive electricity from the public grid, a monopoly supplier, for 89 operating days (adding up all the part or full days) a year (74 days at the median). As a result, many firms invested in a back-up power generator. As many as 77 percent of large firms, 44 percent of medium-sized firms, and 16 percent of small-sized firms owned generators. The cost of generators represented 16 percent of the value of total investment, on average, and 25 percent of the value of investment in equipment and machinery in 1997. Moreover, the data suggest that it costs about three times more to run and own a generator than to buy power from the public grid (when it is available). Errors in billing occurred 3 months per year, on average.

Despite the generally poor quality of public electricity service, there were large variations across firms in terms of days without power (figure 2). These variations were partly the result of unreliable power supply in general, and partly the result of service on specific power lines. For instance, interviews with firm managers suggested that firms connected to "priority" lines (i.e., power lines that connect important army facilities) were more likely to receive reliable power supply.

Access to public telephone service varied by location and firm size. On average, it took 13 weeks to obtain a telephone connection. Over one-half of the firms invested in mobile phones (a privately run service) because public service was so inefficient. Firms tried an average 2.5 times to complete a local call, 4.6 times to complete a long-distance call within Uganda, 4 times to complete a call to a neighboring country, and 2.8 times to complete an international call.

One-third of the firms reported having access to public waste disposal services, but few could actually rely on them. Eight percent of firms used a private provider and 77 percent disposed of their own waste. Similar problems plagued other public capital services, including water supply (firms reported 33 days of inadequate supply in a year), postal services (only 31 percent of business correspondence was delivered by the public post office), ports and airports, road and rail services.

Altogether, the summary statistics suggest that the magnitude of the poor infrastructure and deficient public services is considerable, and therefore might have significant effects on firms' investment and business decisions. In section 4 we formally test if this is the case, and in the next section we present a simple model to guide the empirical work.

3. Model

Consider the following two-period model. A manager maximizes the expected discounted cash flow according to the following quasi-linear preference function

$$w(d_1, d_2) = u(d_1) + E\beta d_2 \tag{3.1}$$

where d_t, $t = 1, 2$, is cash flow in period t, β is a discount factor, E is an expectation operator, and $u(\cdot)$ is a strictly increasing concave function. The firm (manager) starts period 1 with retained earnings e, and must decide how to allocate these earnings between dividends in present period (d_1) and investment i and thereby expected dividends in period 2 (d_2).

The return to private productive capital, i, depends on the availability of complementary capital. There is uncertainty about the availability and quality of publicly provided complementary capital. However, firms can remove the uncertainty by substituting public capital for private substitutes, but there is a fixed cost of doing so. In period 1, the manager decides whether or not to buy complementary capital; that is, private substitutes, denoted by κ, where $\kappa = \{0, \bar{\kappa}\}$. In period 1, the manager also determines the amount of investment, denoted by i. Capital becomes productive in period 2, according to the production function $f(i)$.

Without adequate complementary public capital, the return to private investment is uncertain. The net return is given by $qf(i)$. To simplify, we assume that q can take two values, $\bar{q}$ and $\underline{q}$, with $\bar{q} > r > \underline{q}$. The probability of event $\bar{q}$ $\left[\underline{q}\right]$ is $p_{\bar{q}}$ $\left[p_{\underline{q}}\right]$. Let q^e denote expected q; that is, $q^e = p_{\bar{q}}\bar{q} + p_{\underline{q}}\underline{q}$.

With private complementary capital installed, the firm can ensure at least the net return $rf(i)$, where $\bar{q} > r > \underline{q}$. If public provision turns out to be available

and of good quality, the net return $\bar{q}f(i)$ is higher.[2] Thus, the net return for a firm with installed complementary capital is $\max[q, r]\, f(i)$. q is observed at the beginning of period 2.

We assume an incomplete credit market, implying that firms can only invest from retained earnings, e. The budget constraint in period 1 is then simply

$$d_1 + i + \kappa \leq e\,. \tag{3.2}$$

The firm's problem can be solved by working backwards. In period 1, the firm determines the amount of investment, i. The first-order conditions for the two 'types' of firms are

$$-u'(d_1) + \beta r^e f'(i) = 0 \quad \text{if } \kappa = \bar{\kappa} \tag{3.3}$$

and

$$-u'(d_1) + \beta q^e f'(i) = 0 \quad \text{if } \kappa = 0 \tag{3.4}$$

where $r^e \equiv p_{\bar{q}}\bar{q} + p_{\underline{q}}r$. Equations (3.3) and (3.4), together with the budget constraint (3.2), implicitly define the investment functions

$$i^1 = I^1(e, \beta, r^e, \bar{\kappa}) \tag{3.5}$$

$$i^0 = I^0(e, \beta, q^e) \tag{3.6}$$

where i^1 is the investment function for a firm that installed complementary capital ($\kappa = \bar{\kappa}$), i^0 is the investment function for a firm that did not ($\kappa = 0$). Using the investment functions (3.5) and (3.6), and budget constraint (3.2), to substitute

[2] This seems like a reasonable assumption since complementary capital typically involves large fixed costs and therefore can be supplied cheaper through large-scale production. As an example, the firm survey revealed that it costs about three times more to run and own a generator for power than to buy power from the public grid.

into (3.1), yields the indirect expected utility functions, $w^e(e, r^e, \bar{\kappa} \,|\kappa = \bar{\kappa})$ and $w^e(e, q^e \,|\kappa = 0)$.

Will the firm invest in complementary capital itself? Installing private substitutes is an optimal response if the expected utility of buying private substitutes and investing according to (3.5) is higher than the expected utility of relying solely on public capital and investing according to (3.6). That is, a firm invests $\kappa = \bar{\kappa}$ if,

$$w^e(e, r^e, \bar{\kappa} \,|\kappa = \bar{\kappa}) - w^e(e, q^e \,|\kappa = 0) > 0\,. \tag{3.7}$$

Let $\hat{q}^e$ be the cutoff value of q^e such that

$$w^e(e, r^e, \bar{\kappa} \,|\kappa = \bar{\kappa}) - w^e(e, \hat{q} \,|\kappa = 0) = 0 \tag{3.8}$$

holds. If the firm expects poor quality of complementary public capital; that is $q^e < \hat{q}^e$, the firm will buy private complementary capital. If the firm expects publicly provided complementary capital of high quality; that is $q^e \geq \hat{q}^e$, it will rely solely on public capital.

The investment functions (3.5) and (3.6), and the complementary capital decision (3.8) have some interesting characteristics. First, for a firm that installed private substitutes ($\kappa = \bar{\kappa}$), investment is independent of q^e. Thus, as illustrated in figure 3, a fall in the expected quality of publicly provided complementary capital (due to a lower $\underline{q}$) has no effect on desired investment rate for firms with $\kappa = \bar{\kappa}$, but would result in lower private investment for a firm with $\kappa = 0$.[3]

[3]This asymmetry is due to the fact that firms with $\kappa = \bar{\kappa}$ will always exploit their own privately provided stock of complementary capital when public capital provision is poor, yielding a certain return r on investment. Thus, a lower $\underline{q}$ has no effect. Note though that, for example, a reduction in the probability of efficient public capital provision ($p_{\bar{q}}$), would lower private investment for both "types" of firms, since both r^e and q^e would fall. However, a lower $p_{\bar{q}}$ would reduce the expected return to private investment for a type 1 firm (with $\kappa = \bar{\kappa}$) more than the

Second, a fall in the expected quality of public capital would also affect the decision to buy private substitutes. Note that $\frac{d}{dq^e}\left[w^e\left(\cdot\,|\kappa=0\right)\right] > 0$, and $\frac{d}{dq^e}\left[w^e\left(\cdot\,|\kappa=\bar{\kappa}\right)\right] = 0$, implying that $d\hat{q}/dq^e > 0$. Hence, a fall in the expected quality of public capital would reduce the cutoff value $\hat{q}$ for which it becomes optimal to install private substitutes. Thus, the incentives to 'insure' against bad states increase.

Third, private substitutes crowd-out productive capital; that is, $dI^1/d\bar{\kappa} < 0$. As illustrated figure 3, higher costs of complementary private substitutes, shift the I^1-curve down, as resources that could be utilized for productive public capital is now used to finance private substitutes. If κ is sufficiently large, $I^0 > I^1$ for high q^e.

Finally, a mean-preserving spread in q would also result in more firms buying private substitutes. That is, even though firms are risk neutral with respect to second period cash flows, an increase in the variance of the return q, holding the expected return q^e constant, increases the incentives to buy private substitutes. Intuitively, the option value that follows an installation of complementary capital; that is, the possibility of getting return r when publicly provided capital is of poor quality ($\underline{q}$) increases when the variance in q increases.[4] This result resembles one of the key findings in recent investment under uncertainty theory (see Dixit and Pindyck 1994, for a comprehensive review; and Pattillo, 1997; Svensson, 1999b, for empirical support). The so-called option approach views investment policy as balancing the value of waiting for new information with the cost of foregone

fall in expected return to private investment for a type 2 firm (with $\kappa = 0$). As a result, more firms would find it optimal to buy private substitutes.

[4] A mean-preserving spread implies a higher $\bar{q}$ and a lower $\underline{q}$. Note that a firm with $\kappa = \bar{\kappa}$ is "insured" against the bad outcome ($\underline{q}$), but will take advantage of the good outcome ($\bar{q}$).

returns. When a firm makes an irreversible investment it gives up its option to wait. In this paper we have implicitly assumed away the option-to-wait incentive, since the firm is presumed to always invest in period 1. However, we end up with a similar result since firms have the opportunity to install its own complementary capital, thereby receiving an option value on potential future returns.

The effect of a mean-preserving spread can be illustrated graphically. Figure 4 plots the relationship between investment rates and expected quality of the publicly provided complementary capital for two types of firms:

Type 1. a firm facing an uncertain q with high variance;

Type 2. a firm facing an uncertain q with low variance.

If the firms expect q^e to be larger than q' but smaller than q'', only the firm facing high variance will choose to buy insurance by investing in private substitute, at the cost of less productive capital installed. Thus, if the expected quality of public capital is sufficiently good, a firm facing low variance might choose not buy private substitutes and to invest more in productive capacity.

4. Testing the model

4.1. Empirical specification

In this section, we test the implication of the model on a sample of 171 Ugandan establishments. The two key equations in the model are the investment functions (3.5) and (3.6). From (3.5) and (3.6) it follows that for firms with installed complementary capital, investment should be independent of q^e (or $\underline{q}$), while for firms that lack complementary capital, investment should be a negative function of q^e. Moreover, complementary capital crowds out private investment. Provided

that the quality of public capital is sufficiently good, a firm that installs private substitutes might even invest less than a firm that does not (as illustrated in figure 4).

To estimate equations (3.5) and (3.6) we make linear approximations of $I_0(\cdot)$ and $I_1(\cdot)$, and replace the unobserved q^e with a proxy of realized q, plus a forecast error, ε. Nesting equations (3.5) and (3.6) then yields a testable model

$$i^i = \alpha_0 + \alpha_r r^i + \alpha_\beta \beta^i + \alpha_e e^i + \alpha_d p^i + \alpha_{dq} p^i q + \alpha_q q^i + \varepsilon^i \qquad (4.1)$$

where p^i is a dummy variable taking the value 1 if firm i has invested in complementary public capital and 0 otherwise.

4.2. Data

The data used to estimate equation (4.1) comes from the Ugandan Industrial Enterprise Survey (Reinikka and Svensson, 1999). The survey was initiated by the World Bank primarily to collect data on the constraints facing private enterprises in Uganda, and it was implemented during January-June 1998. A total of 243 firms were interviewed in 5 locations, in 14 different subindustries (three-digit ISIC). We were unable to collect detailed cost and sales or investment data for all firms. Thus we ended up with a smaller sample of 171 firms.

The dependent variable, the investment rate, is measured as investment in machinery and equipment in 1997 excluding potential investment in generators, as a share of the previous period's capital stock, *inv*. As a proxy for p^i, complementary public capital, we use installed electric power generators (*generator*). This is a binary variable taking the value 1 if the firm reported that it owned a generator at the end of the sample period, and 0 otherwise. A logical proxy for q

is then the reported number of days in 1997 that the firm did not receive power from the public grid (*lostdays*).

Retained earnings, e^i is proxied by profits, measured as sales less operating costs and interest payments (*profit*). The unobserved parameters r^i and β^i are proxied by total employment (*size*) and age (*age*). The presumption is that larger and more established firms are more likely to have access to lower cost capital (external finance). The empirical model is hence

$$inv^i = \boldsymbol{\alpha}'\mathbf{x}^i + \alpha_d generator^i + \alpha_q lostdays^i + \alpha_{dq} generator^i * lostdays^i + \varepsilon^i \quad (4.2)$$

where $\mathbf{x}^i = [age^i,\ size^i,\ profit^i]$. To minimize heteroscedasticity problem with respect to size, investment and profits are scaled by the inverse of the end of the previous period capital stock.

4.3. Results

Before proceeding to the results it is useful to take an initial look at some of the data. Table 1 reports summary statistics for the 171 firm sample. 40 percent of the firms owned a generator by the end of the sample period. The size of the generator varied greatly, with a mean of roughly 270 KVA [median 140 KVA] and a standard deviation of 550 KVA, and is highly correlated with the size of the firm. The simple correlation between employment size and owning a generator is 0.37.

As depicted in table 2, firms with installed generators typically are larger, and reported more days in 1997 without power from the public grid. Both results are in accordance with the model. A fall in the expected quality of public capital increases the incentives to buy private substitutes, and due to indivisibilities in

κ, larger firms will find it easier to match available private substitutes to their needs. The two types of firms are similar with respect to age and profit rate (at the median).

Table 3 reports a series of regression, corresponding to equation (4.2). As evident, all three variables of primary interest, *lostdays*, *generator* and the interactive term; enter highly significant.[5] In accordance with the model, the investment level of firms with installed generators is quantitatively independent of q, whereas for firms with no generator, investment is negatively related to number of lost days.[6] Interestingly, firms that had installed complementary capital and experienced few lost days, invested less than firms that did not have a generator. This supports the notion that private complementary capital indeed crowds out private investment; that is, firms that install complementary capital invest less than firms that do not, provided that the quality of public capital is sufficiently good.[7] Regression 2 is illustrated in figure 5. The estimated magnitude of deficient public capital on investment is large. For a firm that relies solely on public capital, a one-standard-deviation deterioration in power supply (evaluated at the mean), would result in an 11-percentage point drop in the investment rate.

To test the robustness of the results, we add additional controls to the base specification in regressions 2-5. Regression 2 adds change in sales ($\Delta sales$). Ac-

[5] One extreme outlier is dropped. Including this observation increases the standard errors on *generator* and the interactive term (*generator*·*lostdays*). However, the three variables of main interest; *lostdays, generator,* and *generator*·*lostdays* are still jointly significant (F-statistic on the joint hypothesis of zero coefficients is 3.37).

[6] We cannot reject the null-hypothesis that $\alpha_q - \alpha_{dq} = 0$. The F-statistic is 0.21 with p-value 0.65.

[7] Note that there is not only a fixed cost of investing in private complementary capital, but that there are also additional maintenance and operating costs. As noted in footnote 2, the data reveals it costs three times more to own and operate a generator for power than to by power from the public grid.

cording to a traditional accelerator model, investment is positively related to demand changes (see for instance Tybout, 1983). However, once we control for profit, $\Delta sales$ has no significant impact. In regression 3, the base specification is augmented with a measure of capacity utilization (*capacity*), and in regression 4, with the percentage of foreign ownership (*foreign*). As evident, neither variable enters significantly. In all three regressions, *lostdays*, *generator*, and the interactive term, remain highly significant.

Regression 5 adds a proxy of the firm managers' perception of the overall quality of public capital (infrastructure services). The variable *quality* enters significantly positive (at the 10 percent level) without affecting the variables of primary interest.

As a further check on robustness of the findings we report the results of some additional sensitivity analysis in table 4. The estimated residuals tend to be larger for the larger firms in the sample (as measured by log of employment). As a possible correction for this heteroscedasticity, we re-estimated the model by weighting observations with employment. The results are shown in regressions 1 and 2 of table 4. Apart from the perception score *quality*, which no longer enters significantly, the results remain similar to those reported in table 3.

In table 5 we re-estimate the model (4.2) with all variables in logs. This has the well-known advantage that the coefficients can be interpreted as elasticities. However, since both *profit* and *investment* can take negative values, we have to add constants to these terms. This in turn implies that the elasticity of investment with respect to these variables are not constant. Column 2 displays the estimated elasticities evaluated at the mean. For a firm lacking private substitutes of complementary capital, a one-percent increase in the number of days without power,

results in a 0.45 percent reduction in investment. As in previous regressions, we cannot reject the hypothesis that $\alpha_q - \alpha_{dq} = 0$. Thus, an increase in number of days lost has no statistically significant effect on investment for firms with their own generators.

5. Conclusion

The role of poor infrastructure and deficient public services in determining level of private capital accumulation has received relatively little attention in the economic literature, and the existing empirical evidence suggest that the effect of public spending and investment on growth is at best ambiguous. This ambiguity may simply be a problem of identification; more spending does not necessarily imply more productive public capital or services. By using firm-level data on outcomes, we overcome this identification problem. We show that poor public capital significantly reduces productive investment by firms. The microeconomic data also shows how firms cope with deficient public capital: when public services are poor they can invests privately in complementary capital. However, there is a cost: less productive capital will be installed.

The results have clear policy implications. If a substantial share of firms' cost items is attributable to the poorly functioning public sector, which is beyond firms' control, private supply responses to macroeconomic policy reform are likely to remain limited without an accompanying improvement in the public sector's performance. Thus, although stabilization and structural adjustment are necessary conditions for sustainable improvement in the private sector, they may not be sufficient to achieve sustained growth and capital accumulation.

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Table 1. Summary Statistics

	Mean	Median	Min	Max	Std. dev.
employment	114	29	5	2,000	252
log(employment)	3.62	3.37	1.61	7.60	1.41
age	13.1	10.0	1	73	12.4
age (log)	2.16	2.30	0	4.29	0.97
profit rate	0.72	0.26	-2.63	9.17	1.55
lostdays	88.7	74	0	365	69.1
log(1+lostdays)	4.04	4.32	0	5.90	1.24
observations	171	171	171	171	171

Table 2. Summary Statistics

	Owns a generator		Does not own a generator	
	Mean	Median	Mean	Median
employment	229	100	36	19
age	14.9	11.0	11.9	8.5
profit rate	0.52	0.28	0.85	0.25
lostdays	102	90	80	60
capacity (KVA)	273	138		
observations	69	69	102	102

Table 3. Investment Regressions[(i),(ii),(iii),(iv)]

Equation Dependent variable	(1) *inv*	(2) *inv*	(3) *inv*	(4) *inv*	(5) *inv*
constant	.407***	.386***	.398***	.411***	.283**
	(.110)	(.112)	(.120)	(.111)	(.129)
profit	.054***	.047***	.052***	.054***	.052***
	(.014)	(.015)	(.014)	(.014)	(.014)
employment (log)	6.8E-4	-.001	-5.5E-4	.005	.004
	(.018)	(.018)	(.018)	(.018)	(.018)
age (log)	-.041*	-.037*	-.040*	-.044**	-.042**
	(.021)	(.021)	(.022)	(.022)	(.021)
lostdays (log)	-.073***	-.068***	-.076***	-.074***	-.069***
	(.020)	(.020)	(.020)	(.020)	(.020)
*lostdays(log)*generator*	.087**	.081**	.089**	.084**	.098***
	(.037)	(.037)	(.037)	(.037)	(.037)
generator	-.329**	-.301*	-.336**	-.311*	-.379**
	(.159)	(.161)	(.161)	(.160)	(.161)
Δsales		.021			
		(.017)			
capacity			4.3E-4		
			(.001)		
foreign				-5.3E-4	
				(5.7E-4)	
quality					.049*
					(.026)
F-statistic[(v)]	4.51	3.88	4.65	4.59	4.22
	(.005)	(.010)	(.004)	(.004)	(.007)
Adjusted R^2	.15	.15	.14	.15	.16
Observations	170	170	168	170	169

Note: (i) dependent variable is investment in machinery in equipment to previous period's capital stock; (ii) OLS regressions; (iii) standard errors in parenthesis; (iv) *** (**) [*] denotes significance at the 1, 5, and 10 percent level; (v) F-test the joint hypothesis that the coefficients on *lostdays, lostdays*generator, generator* are zero, with p-values in parentheses.

Table 4. Investment Regressions[(i),(ii),(iii),(iv)]

Equation Dependent variable	(1) *inv*	(2) *inv*
constant	.353***	.346***
	(.108)	(.121)
profit	.037***	.037**
	(.012)	(.013)
employment (log)	.004	.004
	(.015)	(.015)
age (log)	-.050***	-.050***
	(.018)	(.018)
lostdays (log)	-.052**	-.051**
	(.021)	(.021)
*lostdays(log)*generator*	.074**	.074**
	(.030)	(.031)
generator	-.301**	-.304**
	(.130)	(.132)
quality		.003
		(.023)
F-statistic[(v)]	2.44	2.47
	(.066)	(.064)
Adjusted R^2	.13	.13
Observations	170	169

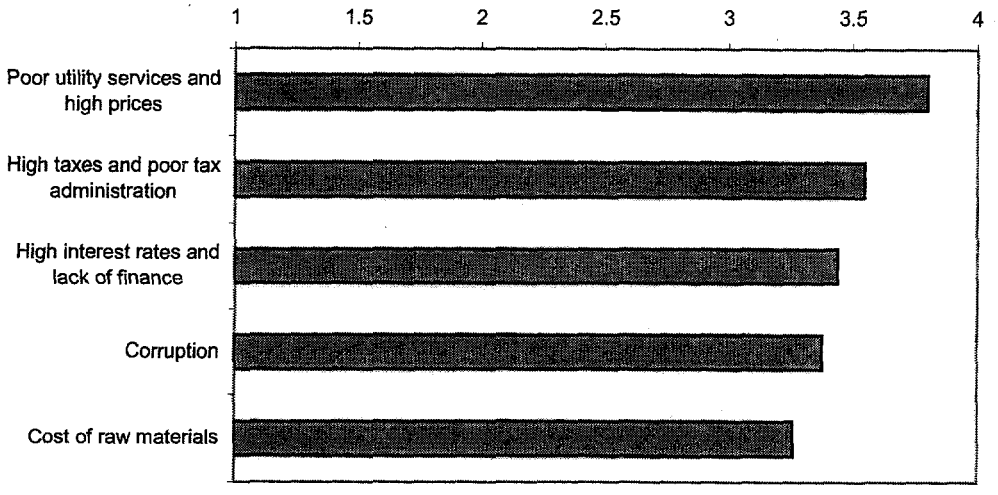
Note: (i) dependent variable is investment in machinery in equipment to previous period's capital stock; (ii) WLS regressions with employment as weight; (iii) standard errors in parenthesis; (iv) *** (**) [*] denotes significance at the 1, 5, and 10 percent level; (v) F-test the joint hypothesis that the coefficients on *lostdays, lostdays*generator, generator* are zero, with p-values in parentheses.

Table 5. Investment Regressions[(i),(ii),(iii),(iv),(v)]

Equation Dependent variable	(1) *log(1+inv)*	(2) *% change*
constant	.067 (.082)	
log(3+profit)	.134*** (.035)	0.34
log(employment)	.005 (.010)	0.06
age (log)	-.030** (.013)	0.40
lostdays (log)	-.034*** (.012)	0.45
*lostdays(log)*generator*	.049** (.022)	0.64
generator	-.185** (.094)	
F-statistic[(vi)]	2.90 (.036)	
Adjusted R2	.12	
Observations	170	170

Note: (i) dependent variable is the logarithm of 1 + investment in machinery in equipment to previous period's capital stock; (ii) OLS regression with employment as weight; (iii) standard errors in parenthesis; (iv) *** (**) [*] denotes significance at the 1, 5, and 10 percent level; (v) percentage change is calculated as $(dinv/inv)/(dx/x)=[(1+inv)/inv]*[x/(a+x)]$ where x is the mean of the explanatory variable and a is relevant constant; (vi) F-test the joint hypothesis that the coefficients on *lostdays, lostdays*generator, generator* are zero, with p-values in parentheses.

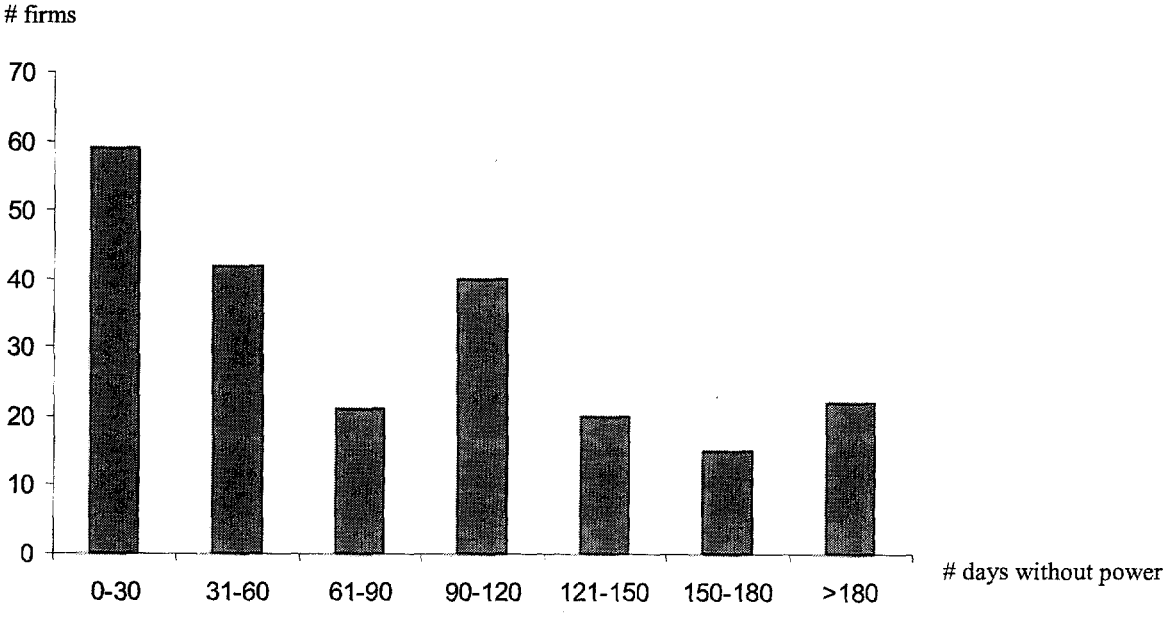
Figure 1: Major Constraints to Investment



1 = no problem, 4 = major problem

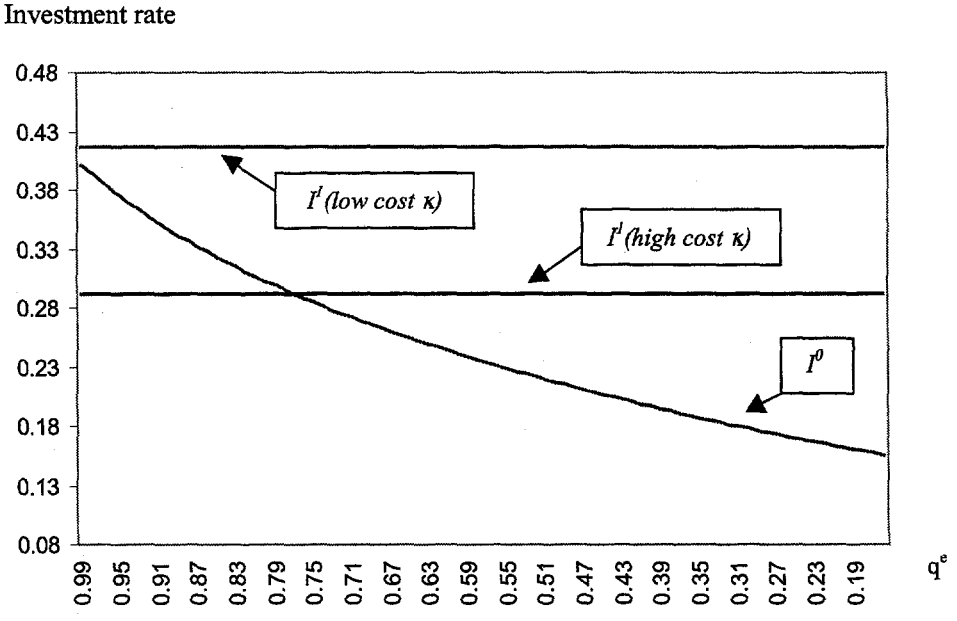
Note: The managers were asked to rank 24 potential bottlenecks. Some of these were close in both ranking and interpretation (poor utility service and high utility prices; high taxes and poor tax administration; high interest rates and lack of access to finance), and were therefore combined.
Source: Reinikka and Svensson, 1999.

Figure 2: Distribution of Firms According to Number of Days Without Power



Source: Authors' calculations

Figure 3. Effect of Poor Infrastructure Quality on Investment Rate



Source: Model simulation

Figure 4. Effect of High Variance in Public Infrastructure Quality on Investment Rate

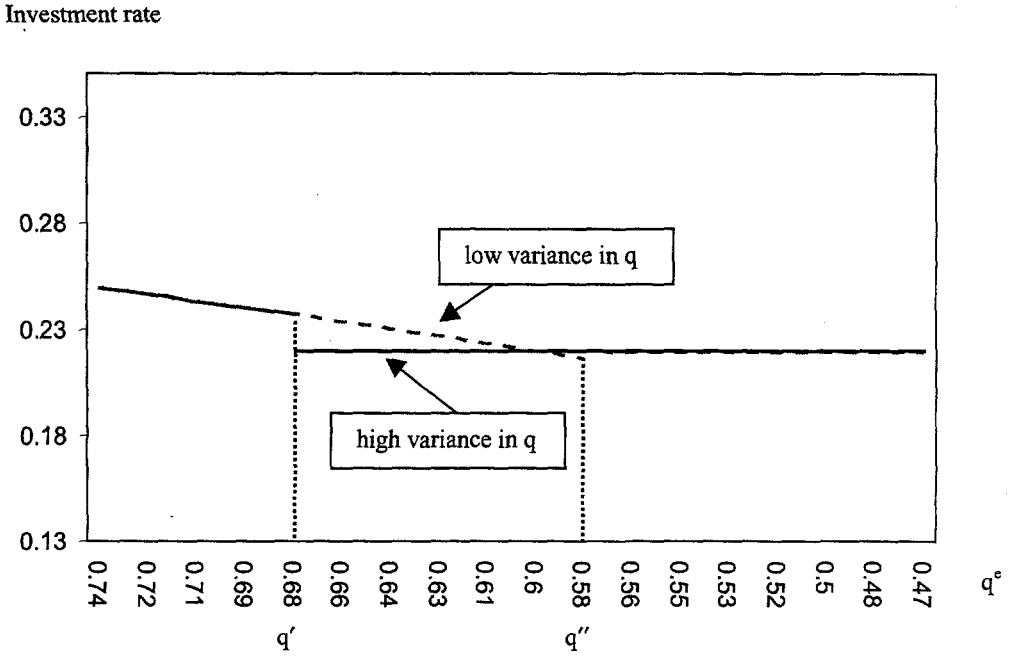
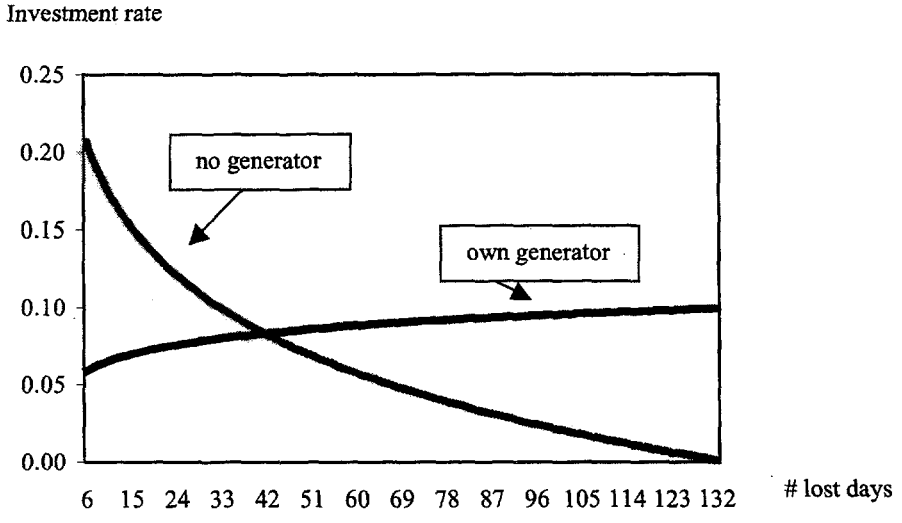


Figure 5. Investment Rates of Ugandan Firms as a Function of Poor Electricity Service



Source: Estimated investment rates based on regression 1, table 3; with all control variables evaluated at the mean.

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